SCIENTIFIC NOTE

Comparative Activity of the Codling Moth Granulovirus Against *Grapholita molesta* and *Cydia pomonella* (Lepidoptera: Tortricidae)

LAWRENCE A. LACEY[1,2], STEVEN P. ARTHURS[1] and HEATHER HEADRICK[1]

ABSTRACT— The granulovirus of codling moth, *Cydia pomonella* L., CpGV, is now commercialized for codling moth control in pome fruit in the USA and Canada. It is highly specific for codling moth and related species. Comparative assays of CpGV against neonate larvae of another introduced tortricid pest, the oriental fruit moth, *Grapholita molesta* Busck, revealed a 557 and 589 fold lower susceptibility of neonate larvae compared with the LC_{50} and LC_{95} values derived for *C. pomonella*.

Since its introduction into North America, the oriental fruit moth, *Grapholita molesta* Busck, has become a widely established pest of peach, nectarine, apricot, and apple (Rothschild and Vickers 1991). There is little information regarding naturally occurring disease of the oriental fruit moth, with the exception of microsporidia in adults (Simchuk and Komarova 1983) and *Bacillus thuringiensis* in larvae (Grassi and Deseö 1984). Although field trials with various formulations of *B. thuringiensis* have been reported for oriental fruit moth, results indicate that it is relatively ineffective (Rothschild and Vickers 1991).

Following its initial discovery in infected codling moth *Cydia pomonella* L. larvae in Mexico in 1964, numerous laboratory and field studies have confirmed the virulence of the codling moth granulovirus (CpGV), against its homologous host (Falcon *et al.* 1968, Laing and Jaques 1980, Arthurs and Lacey 2004, Cossentine and Jensen 2004). In early host specificity studies, CpGV was also noted to have larvicidal activity against the pea moth, *Cydia nigricana* (Fabricius) (Payne, 1981) and oriental fruit moth (Falcon *et al.* 1968), but quantitative assays of the virus have not been reported for the latter species. We conducted bioassays of the Cyd-X formulation of CpGV (Certis USA, Columbia, MD) against oriental fruit moth and codling moth neonates from colonies maintained at the Yakima Agricultural Research Laboratory using the materials and methods described by Lacey *et al.* (2002). The codling moth diet described by Brinton *et al.* (1969) (BioServ, Frenchtown, NJ, USA) was used for both species.

Following initial bioassays to determine mortality ranges, five concentrations of Cyd-X that produced mortality in neonate larvae ranging from 10 to 96.7% in oriental fruit moth and 36.7 to 96.7% in codling moth were bioassayed against 30 neonates per concentration. Bioassays were conducted on artificial diet in 2-ml plastic conical autosampler vials (Daigger, Lincolnshire, IL, USA). A 2-mm diameter hole in the cap of each vial covered with stainless steel screen (0.16 mm mesh size) eliminated condensation. Ten µl of aqueous virus suspensions or 10 µl of water for controls was applied to the surface of 1 ml of artificial medium (approximately 100 mm^2) in the autosampler vials. The label specified virus concentration of Cyd-X is 3×10^{13} granules per liter. After the surface of the medium had dried, one neonate larva was added to each vial. The vials were incubated for 7 d at 25 ± 1.7 °C and then assessed for larval mortality. The study was repeated for each species on four separate dates. Each date was treated as an individual replicate of each concentration (i.e. data were not pooled before probit analysis).

The results of the assays clearly indicated that oriental fruit moth neonates are susceptible to CpGV, but at a significantly lower level than that observed in codling moth neonates (Table 1). The oriental fruit moth were 557 and 589 times less susceptible to CpGV compared with codling moth, based on probit (normal sigmoid) analysis of the LC_{50} and LC_{95}, respec-

[1] Yakima Agricultural Research Laboratory, USDA-ARS, 5230 Konnowac Pass Rd., Wapato, WA 98908
[2] Author to whom correspondence should be addressed

tively (StatsDirect Ltd, v. 2.4). Based on our methods, the calculated LC_{50} and LC_{95} of CpGV for oriental fruit moth are 35 and 540 granules per mm^2, respectively, but only 0.06 and 0.9 granules per mm^2 for codling moth. Although CpGV must be ingested in order to infect a larva, Ballard *et al.* (2000) demonstrated that the point of entry of codling moth larvae into fruit may not necessarily be where virus is acquired; larvae could become infected by walking or browsing on CpGV-sprayed leaf surfaces in as little as 3.5 min. Ostensibly virus picked up on legs or mouth parts in the absence of browsing leaf surfaces could contaminate the initial point of entry. In our bioassays, neonates of both species may wander over the surface of the medium before boring into it. In the case of codling moth larvae this would provide ample opportunity to acquire virus even at the lower concentrations. Huber (1986) estimated that the LD_{50} for neonate larvae could be as low as 1.2 granules per larva.

First generation oriental fruit moth often feed on shoots and young foliage. Although not as active against oriental fruit moth as against codling moth in laboratory bioassays, field activity of Cyd-X against oriental fruit moth neonates at label rates used for codling moth control (0.07-0.44 L/ha) could potentially reduce oriental fruit moth populations if significant feeding of early instars of the first generation occurred on treated foliage. Because natural feeding behavior will influence their susceptibility to CpGV, further field studies are warranted.

We are grateful to Rob Fritts Jr. (Certis) for Cyd-X samples and the Washington Tree Fruit Research Commission for financial support. We thank Don Hostetter and Joel Siegel for helpful reviews of the manuscript.

Table 1.

LC_{50} and LC_{95} values for CpGV bioassayed against *Grapholita molesta* and *Cydia pomonella* neonates. The number of granules per 10 µl is based on dilutions of Cyd-X with a label specified virus concentration of 3 x 10^{13} granules/L. All probit comparisons were significantly different, $P < 0.001$ based on dosage $\log_{(10+1)}$ and adjusted for control mortality (< 7.1%).

Species	n	LC_{50} (95% CI)	LC_{95} (95% CI)	Slope
C. pomonella	714	6.30 (4.74 – 7.91)	91.62 (63.00 – 155.68)	1.41
G. molesta	708	3.51×10^3 ($2.72 - 4.42 \times 10^3$)	5.40×10^4 ($3.66 - 9.04 \times 10^4$)	1.39

REFERENCES

Arthurs, S.P. and L.A. Lacey. 2004. Field evaluation of commercial formulations of the codling moth granulovirus (CpGV): persistence of activity and success of seasonal applications against natural infestations in the Pacific Northwest. Biological Control 31: 388-397.

Ballard, J., D.J. Ellis, and C.C. Payne. 2000. Uptake of granulovirus from the surface of apples and leaves by first instar larvae of the codling moth *Cydia pomonella* L. (Lepidoptera: Olethreutidae). Biocontrol Science and Technology 10: 617-625.

Brinton, F.E., M.D. Proverbs, and B.E. Carty. 1969. Artificial diet for mass production of the codling moth, *Carpocapsae pomonella* (Lepidoptera: Olethreutidae). The Canadian Entomologist 101: 577–584.

Cossentine, J.E. and L.B.M. Jensen. 2004. Persistence of a commercial codling moth granulovirus product on apple fruit and foliage. Journal of the Entomological Society of British Columbia 101: 87-92.

Falcon, L.A., W.R. Kane, and R.S. Bethell. 1968. Preliminary evaluation of a granulosis virus for control of codling moth. Journal of Economic Entomology 61: 1208-1213.

Grassi, S. and K.V. Deseö. 1984. Distribution of *Bacillus thuringiensis* Berl. and prospects of using it in plant protection. Atti Giornate Fitopatologiche 2: 425-433 (in Italian). Review of Applied Entomology 73: 361.

Huber, J. 1986. Use of baculoviruses in pest management programs, pp. 181-202. *In* R.R. Granados and B.A. Federici (eds), The Biology of Baculoviruses, Vol. II: Practical Application for Insect Control. CRC Press, Boca Raton, FL.

Lacey, L.A., P.V. Vail, and D.F. Hoffmann. 2002. Comparative activity of baculoviruses against the codling moth, *Cydia pomonella*, and three other tortricid pests of tree fruit. Journal of Invertebrate Pathology 80: 64-68.

Laing, D.R. and R.P. Jaques. 1980. Codling moth: Techniques for rearing larvae and bioassaying granulosis virus. Journal of Economic Entomology 73: 851-853.

Payne, C.C. 1981. The susceptibility of the pea moth, *Cydia nigricana*, to infection by the granulosis virus of the codling moth, *Cydia pomonella*. Journal of Invertebrate Pathology 38: 71-77.

Rothschild, G.H.L. and R.A. Vickers. 1991. Biology, ecology and control of the oriental fruit moth, pp. 389-412. *In* L.P.S. van der Geest and H.H. Evenhuis (Eds.), Tortricid Pests, Their Biology, Natural Enemies and Control. Elsevier Science Publishers, Amsterdam, The Netherlands.

Simchuk, P.A. and G.F. Komarova. 1983. Microsporidiosis in the oriental peach moth. Zashchita Rasteni 29 (in Russian); Reviews of Applied Entomology 72: 471 (in English).